09/626,979

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publicati n Date
30 November 2000 (30.11.2000)

PCT

(10) International Publication Number
WO 00/72350 A1

(51) International Patent Classification[7]: H01J 9/227, 29/30

(21) International Application Number: PCT/US00/08067

(22) International Filing Date: 27 March 2000 (27.03.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/316,219 21 May 1999 (21.05.1999) US

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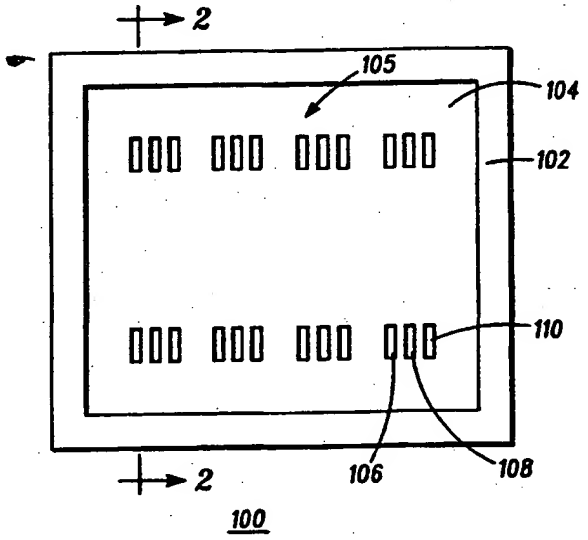
(81) Designated States *(national)*: CN, JP, KR.

(84) Designated States *(regional)*: European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published:
— *With international search report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: FIELD EMISSION DISPLAY ANODE HAVING A CONDUCTIVE MATRIX



(57) Abstract: A field emission display (200) includes a cathode plate (202); a substrate (102) opposing the cathode plate (202); a conductive matrix (104) disposed on the substrate (102) and having via walls (103) defining a plurality of phosphor vias (105); and a phosphor (106, 108, 110) disposed within each of the phosphor vias (105). A method for fabricating the field emission display (200) includes the steps of silk-screening onto the substrate (102) a screenable suspension, which is made from a glass, a metal, and a photo-sensitive material, to form a film; photo-patterning the film to form a phosphor via (105); depositing a phosphor material into the phosphor via (105) to form an anode plate (100); and affixing the cathode plate (202) to the anode plate (100).

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FIELD EMISSION DISPLAY ANODE HAVING A CONDUCTIVE MATRIX

Field of the Invention

The present invention pertains to the area of field emission displays and, more particularly, to an anode plate for a field emission display.

Background of the Invention

Phosphors for field emission displays are known in the art. They can be deposited onto a thin film of indium tin oxide (ITO) formed on a glass substrate. Phosphors can also be covered by a protective metal film, which is included to reflect light, dissipate electrical charge, and to provide mechanical stability to the phosphor material. Several metals may be used for the protective film, the most common being aluminum. To increase viewability, the phosphor is typically located within a non-transparent matrix material. Prior art configurations typically have the phosphor disposed at a depth less than that of the matrix material. This anode plate configuration includes numerous hills and valleys, which makes it difficult to place a smooth protective metal film over the phosphors due to "tenting" of the metal film between features. The "tenting" of the metal film occurs when the metal film spans a gap and is not in contact with the phosphor. Two things generally happen under "tenting" conditions. First, the metal film adhesion is reduced, and can easily be pulled away from the anode plate by high electric fields developed within the field emission display. Second, blisters can form, which are caused by the buildup of organic material in the hills and valleys during processing. In addition, prior art phosphors disposed below the matrix material are required to use smaller, typically less efficient phosphor particle sizes to ensure no gaps exist between particles. This typically makes for a less efficient field emission display.

Accordingly, there exists a need for an improved anode plate that reduces "tenting" of the metal film that is designed to protect the phosphor and improve the efficiency of the display. There further exists a need for an improved anode plate that allows the use of the larger, typically more efficient phosphor particles.

Brief Description of the Drawings

FIG.1 is a bottom plan view of a first embodiment of an anode plate for a field emission display in accordance with the invention;

FIG.2 is a cross-sectional view taken along the section line 2 - 2 of FIG.1 of a field emission display in accordance with the invention; and

FIG.3 is another cross-sectional view taken along the section line 2 - 2 of FIG.1 of a field emission display in accordance with the invention.

It will be appreciated that for simplicity and clarity of illustration, elements shown in the FIGURES have not necessarily been drawn to scale. For example, the dimensions of some of the elements are exaggerated relative to each other. Further, where considered appropriate, reference numerals have been repeated among the FIGURES to indicate corresponding elements.

Description of the Preferred Embodiments

An embodiment of the invention is for a field emission display having an anode structure that includes a conductive matrix, which contains cathodoluminescent phosphors. The phosphors are disposed within phosphor vias defined by the conductive matrix. In the configuration of the invention, the phosphors are disposed at a height equal to or greater than a surrounding conductive matrix material. This has the benefit of eliminating the "tenting" of a protective metal film associated with phosphors that are disposed below the

matrix material. Yet another benefit is that a larger phosphor particle size may be used. Phosphors that are composed of larger phosphor particle sizes are typically more efficient than phosphors that are composed of smaller particle sizes. When the phosphor is configured to be at the same height or greater than the surrounding conductive matrix, phosphors with larger particle sizes can be used since there is sufficient phosphor material to ensure that no gaps exist between the particles which allow electrons to strike the underlying substrate directly. Gaps between the particles will reduce the brightness and efficiency of the display. Still another benefit of the invention is that the conductive matrix provides a conduction path to prevent the accumulation of electrical charge on the phosphors, which would otherwise tend to repel approaching electrons. The conductive matrix can also define the anode electrode of the field emission display thereby obviating the need for a separate anode electrode, such as the ITO layer typically employed in the prior art.

FIG.1 is a bottom plan view of an anode plate 100 for a field emission display in accordance with the invention. Anode plate 100 includes a substrate 102 having a major surface, which is made from a hard, transparent material, such as glass, quartz, sapphire and the like.

A conductive matrix 104 is affixed to the major surface of substrate 102. Conductive matrix 104 includes a thick film that is conductive. Conductive matrix 104 further defines a plurality of phosphor vias 105, which contain the cathodoluminescent phosphors. The embodiment of FIG.1 includes a polychromatic display. So, the phosphor material includes a red phosphor 106, a green phosphor 108, and a blue phosphor 110, which define a plurality of pixels. By way of example, and no way intended to be limiting, the dimensions of phosphor vias 105 are about 50 x 180 micrometers.

However, the present invention is not limited to polychromatic displays and can be embodied by a monochromatic field emission display. The particular phosphor configuration depicted in FIG.1 is exemplary and in no way intended to be limiting.

FIG.2 is a cross-sectional view taken along the section line 2 - 2 of FIG.1 of a field emission display 200 in accordance with an embodiment of the invention. Field emission

display 200 includes anode plate 100 and further includes a cathode plate 202, which opposes anode plate 100. Cathode plate 202 is spaced apart from anode plate 100 by spacers (not shown) to define an interspace region 205 therebetween. Cathode plate 202 includes a substrate 203, upon which are formed a cathode electrode 208 and a plurality of electron emitters 206. Electron emitters 206 oppose phosphor vias 105.

Conductive matrix 104 has a plurality of via walls 103, which define phosphor vias 105. The phosphor material is disposed within phosphor vias 105. In the embodiment of FIG.2, the depth of each of phosphor vias 105 has the same depth as the phosphor 106, 108, 110 disposed therein. As an example, the depth of phosphor vias 105 and phosphor 106, 108, 110 are equal to the thickness of conductive matrix 104, which is about 10 - 12 micrometers. This configuration provides many advantages. For example, larger more efficient phosphor particle sizes can be used since the additional phosphor material ensures that gaps between phosphor particles are filled thereby preventing electrons from missing the phosphor particle and impinging on the substrate directly. This creates a more efficient phosphor layer and a correspondingly more efficient field emission display.

As shown in FIG.2, no protective metal film is formed on the phosphor material. The omission in the present invention of the prior art metal film precludes the attenuation of the energy of the incident electrons, which would otherwise occur upon their traversal of the prior art metal film. This retention of electron energy also improves the efficiency of field emission display 200.

As illustrated in FIG.2, no prior ITO film is formed on substrate 102. Phosphors 106, 108, 110 are disposed within phosphor vias 105 and are affixed to the surface of substrate 102.

Conductive matrix 104 further includes a contrast layer 107 as shown in FIG.2. Contrast layer 107 is disposed on the surface of substrate 102 and is light-absorbing, so that it enhances the contrast of the display image. In the embodiment of FIG.2, contrast layer 107 is made from the glass/metal mixture comprising conductive matrix 104 and further includes a contrast enhancement material, which imparts a dark, light-absorbing color to the

film. This contrast enhancement constituent preferably includes an inorganic oxide, and most preferably, ruthenium oxide, which imparts a black color to contrast layer 107.

The remainder of conductive matrix 104 does not include the inorganic oxide. However, in another embodiment of the invention, conductive matrix 104 does not include a distinct contrast layer 107. Rather, a contrast enhancement material, such as ruthenium oxide, nickel oxide, and the like, is distributed throughout conductive matrix 104. In yet a further embodiment, contrast layer 107 includes black chrome or other "black" metallic like material.

Conductive matrix 104 is made from a mixture of a glass and a conductive material, such as a metal, metal alloy or metallic oxide. Examples of metals include but are not limited to silver, copper, gold, palladium, platinum, combinations thereof, and the like. The conductive material composition of this mixture is within a range of about 5 - 100 per cent by volume. The metallic constituent imparts conductivity to conductive matrix 104. In general, the composition of the conductive material is predetermined to impart to conductive matrix 104 a resistivity that is less than 100 ohm-cm, preferably less than 10 ohm-cm. The glass constituent of conductive matrix 104 includes a glass having a bonding (e.g., melting, sintering) temperature that is less than the strain point temperature of substrate 102.

A further embodiment of the invention is shown in FIG.3, which is the same field emission display 200 as shown in FIG.2, with the addition of protective metal film 220. Protective metal film 220 is preferably but not limited to aluminum and has thickness within a range of about 300 - 1000 angstroms. In the embodiment of FIG.3 protective metal film 220 is disposed over conductive matrix 104 and phosphors 106, 108, 110. This configuration provides many advantages. For example, when phosphors 106, 108, 110 are the same height as surrounding conductive matrix, a smooth surface is created for the application of protective metal film 220. When the protective metal film 220 is applied to a smooth surface, a defect free protective metal film 220 is created which avoids the "tenting" of prior art anode plate configurations. The absence of "tenting" creates a protective metal

film 220 with improved adhesion characteristics and better reflectivity when applied to conductive matrix 104 and phosphors 106, 108, 110.

In yet a further embodiment of the invention, the height of phosphor 106, 108, 110 can be greater than the height of conductive matrix 104 and not include the protective metal film 220. In still another embodiment of the invention, the height of phosphor 106, 108, 110 can be greater than the height of conductive matrix 104 and include the protective metal film 220.

In still yet another embodiment of the invention, the field emission display 200 shown in FIG.2 and FIG.3 may include a conductive film disposed between substrate 102 and conductive matrix 104 and phosphor 106, 108, 110. Conductive film is made from a conductive, transparent material, such as ITO.

In a preferred method for fabricating a field emission display in accordance with the invention, the conductive matrix is formed by first forming on the anode substrate a film containing the glass/metal mixture. The film is further patterned to realize the phosphor vias. The patterning may be realized during the deposition step, such as by screen printing using a screen that defines the pattern of the phosphor vias. Alternatively, the patterning may be realized subsequent to the deposition step, such as by photo-patterning of a film that is deposited by silk-screening. When photo-patterning is employed, the film further includes a photo-sensitive material in an amount sufficient to make the film photo-patternable.

A preferred method for forming field emission display 200 will now be described. Conductive matrix 104 is made using a conductive photo-printable material, which is available from E.I. du Pont de Nemours and Company of Wilmington, Delaware, and sold under the trademark FODEL. Contrast enhancement layer 107 includes FODEL and a contrast enhancement material, which includes an inorganic oxide such as ruthenium oxide and the like. The remainder of conductive matrix 104 can be standard white FODEL without the addition of a contrast enhancement material. The FODEL is a mixture including a glass and a silver metal. A photo-sensitive polymer is added to both FODEL mixtures in a concentration sufficient to impart photo-sensitivity to the dried FODEL film, so that it may

be photo-patterned. FODEL with and without the contrast enhancement material is available from E.I. du Pont de Nemours and Company.

Conductive matrix 104 is made by first forming contrast layer 107 on substrate 102. To form contrast layer 107, FODEL with a contrast enhancement material, which comes in the form of a black paste, is silk screened onto the dry surface of substrate 102 to form a black film. The black film has a thickness within a range of about 3 - 5 micrometers. Substrate 102 is then placed in a low temperature oven, and the black film is dried by heating at about 80°C for about 20 minutes.

Subsequently, the white FODEL paste is silk screened onto the black film. Substrate 102 is then placed in a low temperature oven to dry the white film at a temperature of about 80°C for about 20 minutes.

The dried films are then exposed to collimated ultra-violet light through a mask. The regions of the films that are to be removed are not exposed to the UV light. Thereafter, the films are developed using a sodium bicarbonate solution having a pH of 11. The developing step causes the unexposed regions to be removed, thereby forming phosphor vias 105. The resulting structure is then fired in air in the temperature range of 500°C and 550°C to decompose the photo-sensitive polymer and bond the glass constituent, thereby forming a cohesive structure that is affixed to substrate 102.

Subsequent to the affixation of conductive matrix 104 to substrate 102, phosphor 106, 108, 110 is deposited into phosphor vias 105 by one of several phosphor deposition methods, which are known to one skilled in the art. An exemplary screen printing process for the deposition of phosphor 106, 108, 110 includes using a patterned screen to deposit the phosphor material directly into phosphor vias 105. If a fine pixel pitch is desired, a photo-sensitive polymer binder can be added to the phosphor materials. Then, the different color phosphor materials are sequentially silk screened, photo-imaged, and developed. Thereafter, substrate 102 is heated at about 450°C for about one hour to burn off the photo-sensitive binder. A useful photo-sensitive polymer binder is a mixture of polyvinyl alcohol and ammonium dichromate. Another useful photo-sensitive polymer binder is

polymethylene-p-diazodiphenylamine, which is obtainable from Fairmont Chemical Company of Newark, New Jersey.

Phosphor 106, 108, 110 is affixed within phosphor vias 105 by one of several methods, such as by van der Waals forces, the addition of a cement, the addition of a glue, and the like. For example, a "glue" material can be incorporated into the phosphor paste prior to its deposition into phosphor vias 105. By way of example, the glue material may include Tetraethyl orthosilicate (TEOS) or potassium silicate.

In the preferred embodiment of FIG.2, the electrodes of field emission display 200 include cathode electrode 208, a gate extraction electrode 210, and conductive matrix 104. Gate extraction electrode 210 is spaced apart from cathode electrode 208 by a dielectric layer 212. Each electrode is designed to receive a potential from a potential source (not shown). During the operation of field emission display 200, potentials are applied to effect electron emission from selected ones of electron emitters 206, in a manner known to one skilled in the art. The emitted electrons traverse interspace region 205, to be received by the opposing phosphors 106, 108, 110. The accumulated charge is conducted away from phosphors 106, 108, 110 by conductive matrix 104. This operation of the invention obviates the need for an ITO sublayer, such as is employed in the prior art for the purposes of providing the anode potential and conducting charge away from the phosphors.

In the embodiment of FIG.2, the invention is embodied by a triode display. It is desired to be understood that the present invention can also be embodied by a diode display and by displays having greater than three electrodes, including, for example, focusing electrodes.

In one embodiment, subsequent to the deposition of phosphors 106, 108, 110, protective metal film 220 is formed thereon. Protective metal film 220 preferably includes a thin layer of aluminum, having a thickness within a range of about 300 - 1000 angstroms. A standard aluminization process may be employed, as is known to one skilled in the art.

In summary, a field emission display according to the invention includes an anode plate that has a conductive matrix, which contains the phosphor disposed at a height equal to

or greater than the height of the conductive matrix. This has the benefit of eliminating the "tenting" of the protective metal film associated with prior art anode plate configurations. Yet another benefit is the ability to use larger, more efficient phosphor particles. This increases the efficiency of the field emission display. The anode plate of the invention obviates the need for the ITO conductive film and the protective metal film of the prior art. Methods for forming the conductive matrix of the invention do not require the use of a photo-resist.

While we have shown and described specific embodiments of the present invention, further modifications and improvements will occur to those skilled in the art. We desire it to be understood, therefore, that this invention is not limited to the particular forms shown and we intend in the appended claims to cover all modifications that do not depart from the spirit and scope of this invention.

CLAIMS

1. A field emission display comprising:

a cathode plate having a plurality of electron emitters;

a substrate having a major surface opposing the plurality of electron emitters of the cathode plate;

a conductive matrix disposed on the major surface of the substrate having a plurality of via walls defining a plurality of phosphor vias, and wherein the conductive matrix has a first height; and

a phosphor disposed within each of the plurality of phosphor vias, and wherein each of the phosphors has a second height and wherein the second height of the phosphor is at least equal to the first height of the conductive matrix.

2. The field emission display of claim 1, wherein the conductive matrix has a resistivity that is less than 100 ohm-cm.

3. The field emission display of claim 1, wherein the conductive matrix comprises a mixture including a glass and a conductive material, the mixture having a composition of the conductive material within a range of 5-100 percent by volume.

4. The field emission display of claim 3, wherein the conductive material is selected from a group consisting of a metal, metal alloy and metallic oxide.

5. The field emission display of claim 1, wherein the conductive matrix includes a contrast enhancement material in an amount sufficient to enhance light absorption by the conductive matrix.

6. The field emission display of claim 1, wherein the conductive matrix is adapted to receive an anode potential for the field emission display.

7. The field emission display of claim 1, wherein the conductive matrix includes a contrast layer disposed on the major surface of the substrate.

8. A method for fabricating a field emission display comprising the steps of:

providing a cathode plate having a plurality of electron emitters;

providing a substrate having a major surface;

providing a mixture having a metal composition within a range of 5-100 percent by volume;

forming a screenable suspension including the mixture;

depositing through a screen the screenable suspension onto the major surface of the substrate to provide a film;

patterning the film to form a plurality of phosphor vias, thereby realizing a conductive matrix, wherein the conductive matrix has a first height;

affixing a phosphor having a second height within each of the plurality of phosphor vias, wherein the second height of the phosphors is at least equal to the first height of the conductive matrix, thereby realizing an anode plate; and

affixing the cathode plate to the anode plate.

9. The method for fabricating a field emission display as claimed in claim 8, wherein the step of providing a mixture includes providing a mixture having a metal composition in amount sufficient to impart to the conductive matrix a resistivity that is less than 100 ohm-cm.

10. The method for fabricating a field emission display as claimed in claim 8, further including the step of dissolving a photo-sensitive material into the screenable

suspension in an amount sufficient to make the film photo-patternable, and wherein the steps of depositing through a screen and patterning the film include the steps of silk-screening the screenable suspension and thereafter photo-patterning the film.

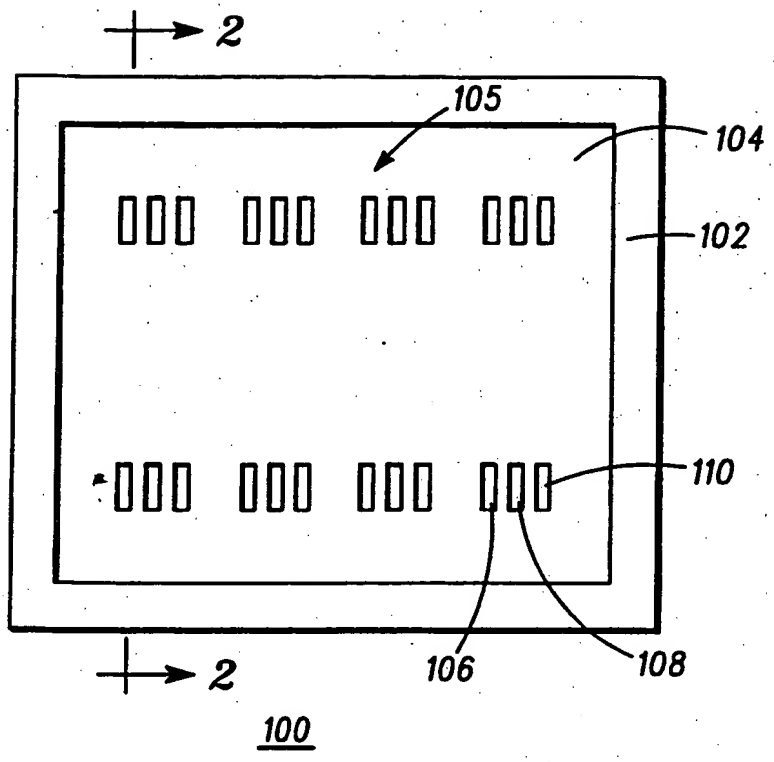
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FIG. 1

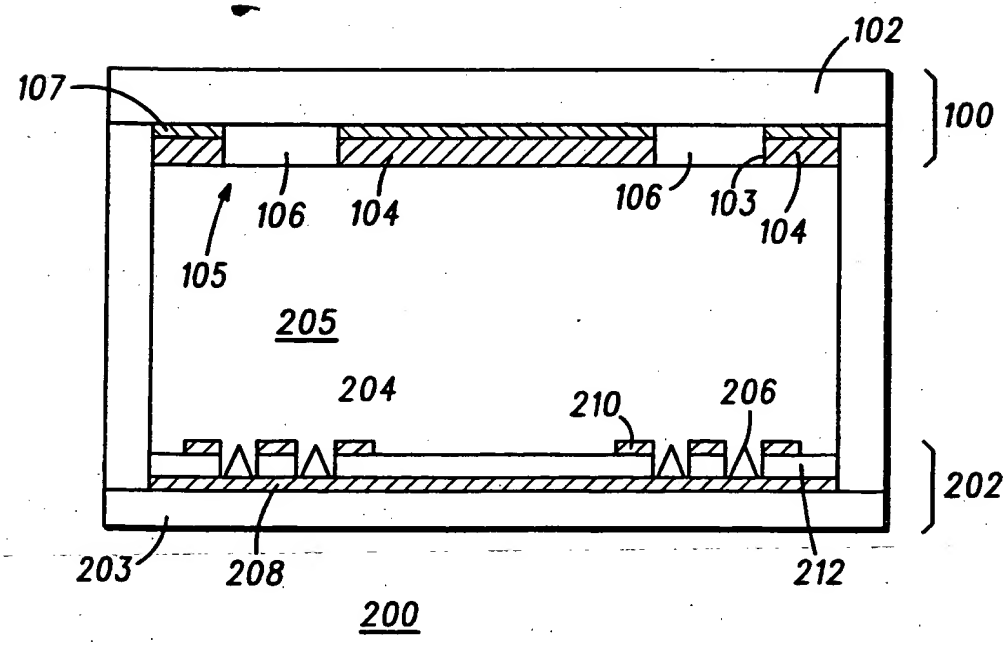
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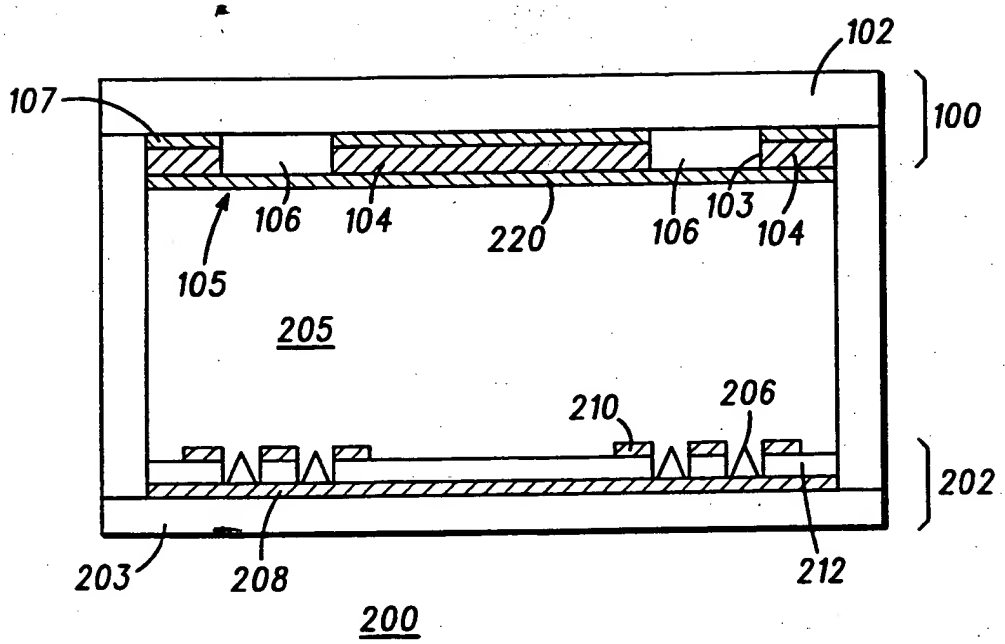
FIG. 2


102
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200

FIG. 3

INTERNATIONAL SEARCH REPORT

Inte. ..ional Application No:
PCT/US 00/08067

A. CLASSIFICATION OF SUBJECT MATTER
H01J9/227,H01J29/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PATENT ABSTRACTS OF JAPAN vol. 7, no. 190, 19 August 1983 & JP 58 093139 A (HITACHI SEISAKUSHO KK) 02 June 1983, --	1-10
Y	WO 99/00822 A (MOTOROLA INC) 07 January 1999, the whole document. --	1-10
A	US 5463273 A (KATO et al.) 31 October 1995, the whole document.	1,8

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
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Date of the actual completion of the international search
04 June 2000

Date of mailing of the international search report
30.08.00

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ANHANG

Zum internationalen Recherchenbericht über die internationale Patentanmeldung Nr.

ANNEX

To the International Search Report to the international Patent Application No.

PCT/US 00/08067 SAE 277464

ANNEXE

Au rapport de recherche international relativ à la demande de brevet international n°

In diesem Anhang sind die Mitglieder der Patentfamilien der im obengenannten internationalen Recherchenbericht angeführten Patentdokumente angegeben. Diese Angaben dienen nur zur Unterrichtung und erfolgen ohne Gewähr.

This annex lists the patent family members relating to the patent documents cited in the above-mentioned search report. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

La presénte annexe indique les membres de la famille de brevets relatifs aux documents de brevets cités dans le rapport de recherche international visée ci-dessus. Les renseignements fournis sont donnés à titre indicatif et n'engagent pas la responsibilité de l' Office.

Im Recherchenbericht angeführte Patentdokumente Patent document cited in search report Document de brevet cité dans le rapport de recherche	Datum der Veröffentlichung Publication date Date de publication	Mitglied(er) der Patentfamilie Patent family member(s) Membre(s) de la famille de brevets	Datum der Veröffentlichung Publication date Date de publication
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